Indian Journal of Science and Technology, *Vol 10(5), DOI: 10.17485/ijst/2017/v10i5/108778, February 2017*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Non-invasive Estimation of Oxygen Saturation Level in Blood

Chelli N. Devi* and Zachariah C. Alex

VIT University, Vellore – 632014, Tamil Nadu, India; chelli@rocketmail.com, zcalex@gmail.com

Abstract

Background: Oxygen saturation level in blood is obtained invasively or non-invasively. Presently, non-invasive approaches which entail photoplethysmographic (PPG) signals are common. **Methods:** This work identifies oxygen saturation non-invasively with PPG waves at 660 and 940 nmthrough LabVIEW. The approach is tested in twelve subjects. **Findings:** Investigations indicate normal saturation from 90 to 97.5% in all people. **Improvements:** Novelty of work is PPG signal simulation for testing LabVIEW blocks. Besides, this technique is easy, painless, fast and therefore highly acceptable.

Keywords: LabVIEW, Non-invasive Approach, Oxygen Saturation, Photoplethysmographic Wave

1. Introduction

It is essential to monitor oxygen saturation in blood. For this, various direct techniques like invasive blood collection and subsequent analysis by gas sampling exist. In addition, there are non-invasive approaches including pulse oximetry which utilizes Photo-Plethysmo-Graphic (PPG) waves at two wavelengths to attain oxygen saturation level. Non-invasive techniques are easy, painless and facilitate continual assessments. Furthermore, they are accurate with variations <2% between the direct and non-invasive evaluations[1].

Recent literature encompasses various non-invasive techniques to find oxygen saturation of blood. These are explicated here. For instance, free flap oxygen saturation is attained to enable prolonged measurement[2]. Likewise, oxygen saturation and perfusion are computed at total and venous occlusion in 21 normal people[3]. Also, real time PPG is utilized in finding heart rate variability; readings are got for sitting and standing postures[4]. Besides, the hemoglobin quantity in blood is identified using PPG waves acquired with NIR source[5].

Similarly, blood glucose and pressure are attained using PPG[6]. The salient aspect is absence of calibration. Sometimes, oxygen saturation is got after incorporating PPG scale parameters to nullify extraneous sources[7]. Few approaches attain regional venous saturation with PPG[8]. Respiratory and heart rates are got with PPG spectral density. The merits involve outlier resistance and absence of demodulation, cycle demarcation, etc.[9]. Notably, oxygen saturation and heart rate are obtained via mobile applications[10].

A few works investigate oxygen saturation with altitude to determine acceptable range[11]. Also, PPG variability with vascular resistance is elucidated in ICU subjects[12]. Further, saturation levels are found in instances of artificial hypothermia i.e. decreased temperatures[13]. Similarly, saturation is found in 20 people with artificial hypoperfusion[14]. Here, trans-reflectance mode is advantageous relative to traditional reflectance and transmittance approaches.

Various approaches identify PPG signal quality to gauge artifacts and anomalous morphology[15]. Specifically, few techniques entail elimination of PPG motion artifacts before finding oxygen saturation. Empirical decomposition is utilized in few instances[16] whereas adaptive coefficient estimation is involved at other cases[17].

**Author for correspondence*

This paper presents a non-invasive approach to gauge oxygen saturation in blood using PPG wave through LabVIEW analysis. Its novelty is simulation of PPG waves in LabVIEW for testing the various blocks prior to acquiring subject data. The paper explicates the methodology, results and discussion, and conclusion.

2. Methodology

Humphreys[18] presents oxygen saturation by

$$Oxygen\ saturation = \frac{OxyHb}{Total\ Hb} \times 100\% \quad (1)$$

Here, OxyHb symbolizes oxyhaemoglobin whereas total Hb connotes both oxyhaemoglobin and reduced haemoglobin in blood. In order to indirectly estimate the ratio of oxyhaemoglobin and total haemoglobin, this work acquires PPG signals at two wavelengths, namely, red (660 nm) and infrared (940 nm). The block diagram and corresponding experimental setup are depicted by Figures 1 and 2.

Figure 1. Block diagram.

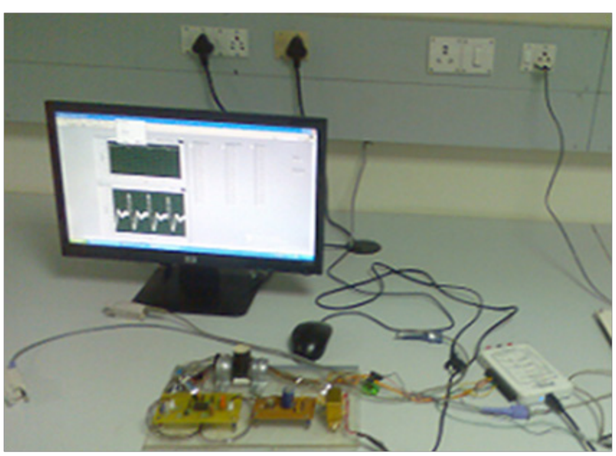

Figure 2. Experimental setup to measure oxygen saturation level.

The setup comprises of Nellcor finger probe to perceive blood flow. It houses red LED at peak wavelength 660 nm and allied photodetector. Likewise, an infrared probe with infrared LED (peak wavelength 940 nm) and associated photodetector is also utilized. These two probes are employed one after the other so as to attain the required PPG waves.

The next phase is signal conditioning. This entails Butterworth low-pass filter to eliminate higher frequency artifacts, followed by signal amplification. Next, myDAQ card from National Instruments is utilized for acquiring subjects' PPG waves and displaying them in LabVIEW. Here, myDAQ card is preferred for its easy and efficient acquisition and portability.

Further, the virtual instrumentation platform of LabVIEW is entailed in signal analysis. LabVIEW is favoured for its uncomplicated and flexible approach, coupled with its ability to meet specific, custom built needs. Besides, LabVIEW offers easy debugging and is apposite for standalone uses given its easy storage and retrieval aspects. Primarily, the PPG waveform is simulated in LabVIEW by a combination of sine and cosine waves of appropriate frequencies and amplitudes. This is to ensure that the developed LabVIEW blocks are first tested with the simulated PPG waveform prior to subject data acquisition.

Subsequently, LabVIEW blocks for acquisition and analysis of subjects' PPG waves are developed. Figure 3 portrays the LabVIEW block designed for acquiring PPG signal at wavelengths 660 and 940 nm. Further, analysis of these PPG waves entails amplitude and level measurements blocks of LabVIEW to derive the ratio $Val_{660nm/940nm}$. This ratio is utilized in obtaining oxygen saturation of blood.

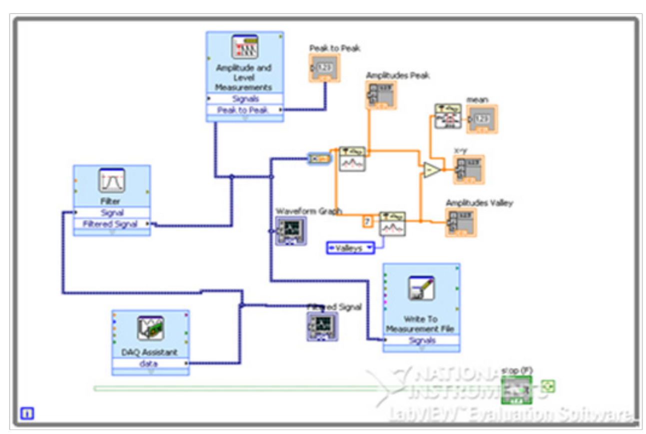

Figure 3. LabVIEW block for acquiring PPG waveform.

Various works[19,20] have propounded different relations between the derived ratio and oxygen saturation. The relation in[21] that oxygen saturation is 98.5 times the acquired ratio (that is, $Val_{660nm/940nm}$) is used in this work. Finally, the attained oxygen saturation is displayed numerically as well as by a level indicator (or vertical progress bar) in LabVIEW.

3. Results and Discussion

The simulated PPG waveform in LabVIEW is depicted in Figure 4. It is observed that the simulated wave closely resembles the PPG obtained in real time. Further, this work entails testing on 12 subjects. The attained $Val_{660nm/940nm}$ ratio and consequent oxygen saturation level in every case is provided in Table 1. Also, the obtained PPG waves at 660 nm and 940 nm for five subjects are displayed in Figure 5.

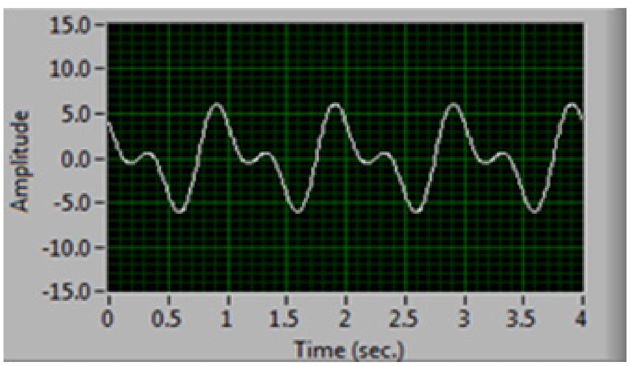

Figure 4. Simulated PPG wave in LabVIEW.

Table 1. Computation of oxygen saturation level.

Subjects	$Val_{660nm/940nm}$	Oxygen saturation level (%)
1	0.952509	93.8221
2	0.976290	96.1646
3	0.984980	97.0205
4	0.959965	94.5566
5	0.969550	95.5007
6	0.926792	91.2890
7	0.975718	96.1082
8	0.934431	92.0415
9	0.948003	93.3783
10	0.920379	90.6573
11	0.958575	94.4196
12	0.935359	92.1329

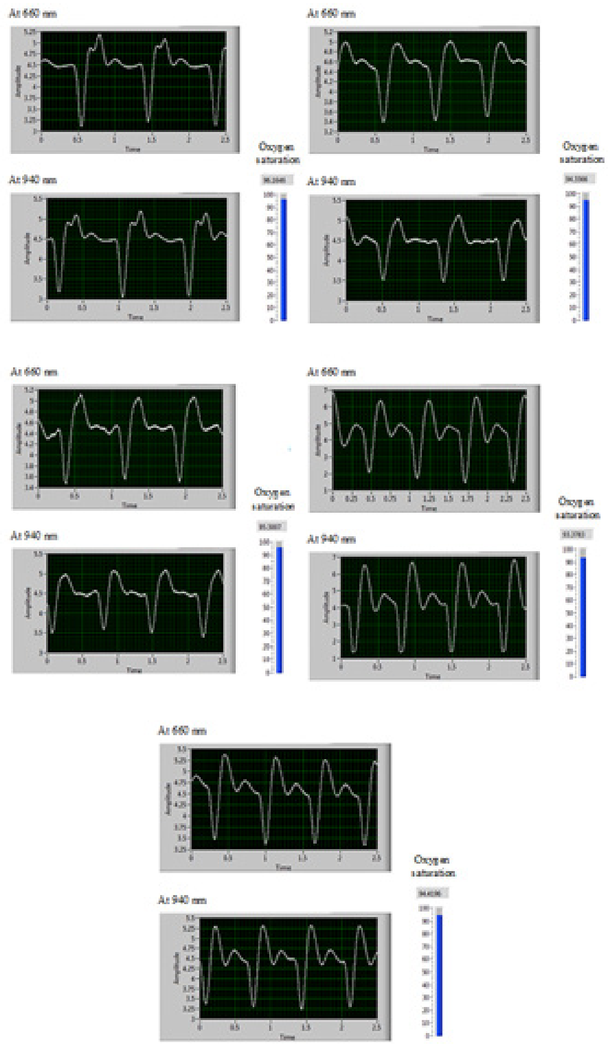

Figure 5. (a) – (e) Acquired PPG waveforms at 660 and 940 nm for five subjects

Various studies have shown that oxygen saturation level less than 80% is deemed 'low' whereas that between 90 and 97.5% is 'normal' and greater than 97.5% is adjudged 'high'. As observed from Table 1, the twelve subjects examined here report normal saturation. Moreover, the proposed method found high acceptability among subjects owing to its easy, safe, painless, fast and reliable procedure without side effects.

4. Conclusion

This work expounds non-invasive approach for finding oxygen saturation using LabVIEW. Its novelty is PPG signal simulation to test developed LabVIEW blocks. In future, this work can be extended to obtain other parameters like glucose non-invasively. This has enormous potential and clinical worth, more so in diabetics and borderline patients.

5. References

1. Collins JA, Rudenski A, Gibson J, Howard L, O'Driscoll R. Relating Oxygen Partial Pressure, Saturation and Content: the Haemoglobin–Oxygen Dissociation Curve, Breathe. 2015; 11:194–201.
2. Zaman T, Kyriacou PA, Pal SK. Free Flap Pulse Oximetry Utilizing Reflectance Photoplethysmography. Proceedings of 35th EMBC, Japan, 2013, p. 4046–49.
3. Abay TY, Kyriacou PA. Reflectance Photoplethysmography as Noninvasive Monitoring of Tissue Blood Perfusion, IEEE Transactions on Biomedical Engineering. 2015; 62(9):2187–95. https://doi.org/10.1109/TBME.2015.2417863 PMid: 25838515
4. Zainal NI, Sidek KA. Real Time PPG Data Acquisition with GUI based Application for HRV Measurement, Indian Journal of Science and Technology. 2016; 9(28):1–5.
5. Abbas AM, Ashok S, Kumar SP, Balavenkateswarlu P. Haemoglobin Detection in Blood by Signal to Image Scanning using Photo-Plethysmo-Graphic-Technique (PPG), Indian Journal of Science and Technology. 2016; 9(1):1–4.
6. Moreno EM. Non-Invasive Estimate of Blood Glucose and Blood Pressure from a Photoplethysmograph by Means of Machine Learning Techniques, Artificial Intelligence in Medicine. 2011; 53(2):127–38. https://doi.org/10.1016/j.artmed.2011.05.001 PMid:21696930
7. Carni DL, Grimaldi D, Sciammarella PF, Lamonaca F, https://doi.org/10.1109/memea.2016.7533775
8. Shafqat K, Langford RM, Kyriacou PA. Estimation of Instantaneous Venous Blood Saturation using the Photoplethysmograph Waveform, Physiological Measurement. 2015; 36(10):2203–14. https://doi.org/10.1088/0967-3334/36/10/2203 PMid:26365652
9. Garde A, Karlen W, Ansermino JM, Dumont GA. Estimating Respiratory and Heart Rates from the Correntropy Spectral Density of the Photoplethysmogram, PLoS ONE. 2014; 9(1):1–11. https://doi.org/10.1371/journal.pone.0086427 PMid:24466088 PMCid:PMC3899260
10. Wannenburg J, Malekian R. Body Sensor Network for Mobile Health Monitoring, a Diagnosis and Anticipating System, IEEE Sensors Journal 2015; 15(12):6839–52. https://doi.org/10.1109/JSEN.2015.2464773
11. Aznar TL, Aguilar GP, Espot AG, Ciria SB, Gorostidi JLM, Alonso DD, Romero JB. Estimation of Arterial Oxygen Saturation in Relation to Altitude, Medicina Clinica. 2016; 147(10):435–40.
12. Middleton PM, Chan GSH, Steel E, Malouf P, Critoph C, Flynn G, O'Lone E, Celler BG, Lovell NH. Fingertip Photoplethysmographic Waveform Variability and Systemic Vascular Resistance in Intensive Care Unit Patients, Medical and Biological Engineering and Computing . 2011; 49(8):859–66. https://doi.org/10.1007/s11517-011-0749-8 PMid:21340639
13. Shafique M, Kyriacou PA. Photoplethysmographic Signals and Blood Oxygen Saturation Values during Artificial Hypothermia in Healthy Volunteers, Physiological Measurement. 2012; 33(12):2065–78. https://doi.org/10.1088/0967-3334/33/12/2065 PMid:23171523
14. Shafique M, Kyriacou PA, Pal SK. Investigation of Photoplethysmographic Signals and Blood Oxygen Saturation Values on Healthy Volunteers During Cuff-Induced Hypoperfusion using a Multimode PPG/ SpO2 Sensor. Medical and Biological Engineering and Computing. 2012; 50(6):575–83. https://doi.org/10.1007/s11517-012-0910-z PMid:22555629
15. Karlen W, Kobayashi K, Ansermino JM, Dumont GA. Photoplethysmogram signal quality estimation using repeated Gaussian filters and cross-correlation. Physiological Measurement. 2012; 33(10):1617–29.https://doi.org/10.1088/0967-3334/33/10/1617 PMid:22986287
16. Raghuram M, Sivani K, Reddy KA. E2MD for Reduction of Motion Artifacts from Photoplethysmographic Signals. Proceedings of ICECS, India, 2014, p. 1–6.
17. Ram MR, Sivani K, Reddy KA. Utilization of Adaptive- https://doi.org/10.1109/wispnet.2016.7566247
18. Humphreys KG. An Investigation of Remote Non-Contact Photoplethysmography and Pulse Oximetry, Department of Electronic Engineering, National University of Ireland; 2007.
19. Fine I, Wienreb A. Multiple Scattering Effect in Transmission Oximetry, Medical and Biological Engineering and Computing. 1995; 33:709–12. https://doi.org/10.1007/BF02510791 PMid:8523915
20. Wieben O. Light Absorbance in Pulse Oximetry. In: Design https://doi.org/10.1887/0750304677/b470c4 https://doi.org/10.1201/9781420050790.ch4
21. Wongjan A, Julsereewong A, Julsereewong P. Continuous Measurements of ECG and SpO2 for Cardiology Information System. Proceedings of the IMECS, Hong Kong, 2009, p. 1537–40.